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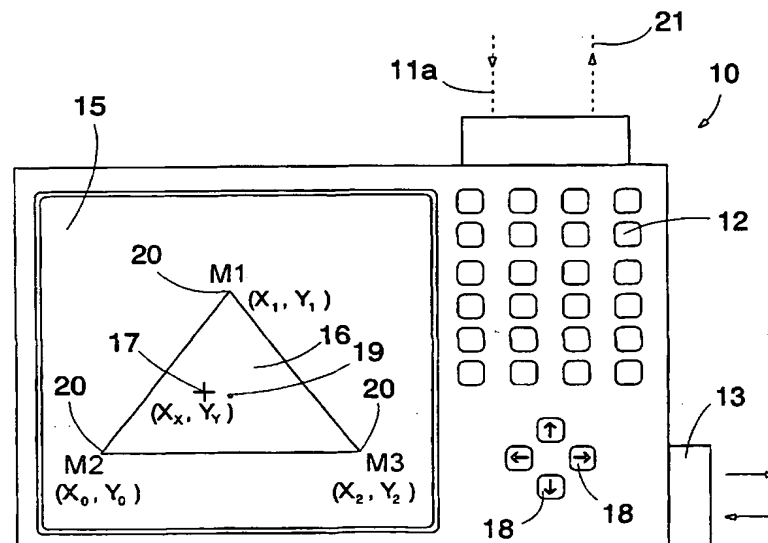
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[Continued on next page]

(54) Title: DRILLING CONTROL ARRANGEMENT



(57) Abstract: A method and a control system for controlling rock drilling. A control unit (10) of a rock drilling apparatus is provided with one or more control modes (M1 - M4), each determining the drilling variables to be measured, their threshold values and the operating principles according to which the operating parameters of drilling are controlled to achieve a desired control criterion. According to a preferred embodiment of the invention, a user interface of the control system comprises a polygonal operating area (16) comprising in each corner (20) one control mode (M1 - M4). When the operating point in the operating area (16) has been selected, the control system calculates the distance from the operating point to each corner (20) and determines a coefficient for each control mode (M1 - M4) to be taken into account in determination of the drilling parameters.



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## DRILLING CONTROL ARRANGEMENT

The invention relates to a method of controlling rock drilling, the method comprising drilling rock with a rock drilling apparatus comprising a carrier, a feeding beam, a rock drill movable with respect to the feeding beam, and a control unit for controlling the rock drilling, the method also comprising  
5 providing a memory of the control unit with default settings for drilling, measuring the operation of the apparatus during drilling, and adjusting the operating parameters of drilling to accomplish a desired control operation.

The invention further relates to a control system for a rock drilling  
10 apparatus comprising a carrier, a feeding beam, a rock drill movable with respect to the feeding beam, a control unit provided with a user interface for controlling the drilling, and at least one sensor for measuring drilling operation.

Rock drilling utilizes a rock drilling apparatus comprising a carrier, a feeding beam and a rock drill moved with respect to the feeding beam. The  
15 rock drill comprises a percussion device for delivering impacts on a tool connected to the drill, and a rotating device for rotating the tool. The rock drill further comprises means for guiding a flushing agent into a drill hole for flushing drill cuttings out of the hole. Operating parameters of rock drilling include impact pressure, feed pressure, rotation pressure medium flow and flushing  
20 pressure, which are adjusted in order to control the operation of the drilling apparatus as desired. In a widely used control arrangement the aim is to provide the drill bit with a maximum penetration rate. This arrangement comprises measuring the penetration rate of the drill bit and empirically adjusting individual operating parameters to achieve the highest possible penetration rate. The  
25 aim of another generally used control arrangement is to optimise transfer of energy from the drill to the rock. This arrangement comprises measuring the rotation power and/or rotation torque of the drill bit and keeping the variables in predetermined limits by adjusting individual operating parameters.

A disadvantage of the prior art methods is that when the operator is  
30 adjusting individual operating parameters, he/she cannot perceive the effect of the adjustment measures to the entire drilling situation and the total costs of drilling. Therefore it is very difficult to optimise drilling by adjusting individual absolute values. Adjustment of a single drilling parameter affects positively certain target criteria representing the success of drilling, but it can simultaneously  
35 affect other target criteria negatively. For example, an increase in impact power expedites drilling and thus reduces the costs of drilling, but unfortunately

the service life of the drilling equipment simultaneously decreases, which in turn adds considerably to the costs of drilling. In all, in the present systems successful adjustment and control of a drilling situation is highly dependent on the experience and skills of the operator.

5           An objective of the present invention is to provide a new and improved arrangement for controlling rock drilling.

          The method according to the invention is characterized by providing the control unit with at least two control modes with different control strategies, each control mode determining at least one criterion to be measured during  
10   drilling, a threshold value for a measurement result, and at least one adjustable operating parameter, prioritising one control mode over the other modes, and calculating, based on the measurement results, control values for the operating parameters to be adjusted in the control unit in order to automatically control the drilling such that the control strategy of the prioritised control mode is  
15   weighted.

          Further, the control system according to the invention is characterized in that the user interface of the control unit is provided with at least two preformed control modes, each control mode has a particular control strategy and determines at least one criterion to be measured during the drilling, a  
20   threshold value for a measurement result, and at least one adjustable operating parameter, one control mode can be prioritised over the other modes, and the control unit is arranged to automatically adjust, based on the measurement results, the operating parameters determined by the control modes such that the drilling result according to the prioritised control mode is weighted over the  
25   other control modes.

          According to an essential idea of the invention, a number of control modes with different weighting required to optimise rock drilling are determined in a control unit of a rock drilling apparatus. According to the control strategy of each control mode, one or more critical control criteria are measured and indi-  
30   vidual operating parameters are adjusted automatically in a manner determined by the control mode in order to achieve a desired state of the control mode. In practice, the control system forms, by means of the control mode, coefficients used to determine allowed limits for measurement results and adjusts individual operating parameters. Default settings of the rock drilling apparatus, which are also required in the control, are stored in advance in the control  
35   unit and are taken into account in adjusting the operating parameters.

A criterion to be measured, determined in a control mode, represents the effect of adjusting one or more operating parameters of drilling, this effect being measured either directly by sensors or calculated in the control unit of the rock drilling apparatus from measurement data obtained from the sensors.

The invention has the advantage that the control modes facilitate the control of drilling performed by the operator of the rock drilling apparatus. The control modes clearly describe how an individual control action affects the entire drilling situation. The operator can select the control mode optimising the target criterion that he/she considers the most important. Furthermore, the operator can switch from one control mode to another in a simple manner even during drilling as the circumstances of drilling or the control targets change.

According to an essential idea of an embodiment of the invention, the control unit comprises a user interface, where the control modes are arranged in corners of a plane geometrical polygon. The area defined by the polygon thus determines the available operating area, where the operator can move a control cursor or the like during adjustment. The location of the control cursor in the operating area illustrates the selected operating point. The closer the operating point is to a single corner of the polygon and thus an individual control mode, the greater the importance of the control mode. Due to the geometrical shape of the operating area, transfer of the control cursor closer to a corner moves the operating point further from the other corners and the control modes determined therein. An advantage of this embodiment is that the operator can weight, in a simple manner, a control mode he/she considers to be important. The user interface also clearly shows how prioritising one control mode also affects the other target criteria of drilling. Furthermore, since prioritising one control mode automatically diminishes the importance of the other modes, the operator cannot give the control system such unreasonable control commands that might conflict with one another and thus cause problems in the operation of the drilling apparatus. In practice, the control unit uses the location of the control cursor to calculate a weighting coefficient for each control mode, and values of the individual operating parameters based on the weighting coefficients.

The invention will be described in more detail in the accompanying drawings, in which

Figure 1 is a schematic side view of a rock drilling apparatus,

Figure 2 shows schematically a control unit according to the invention and a user interface thereof,

Figure 3 shows schematically another control unit according to the invention and a user interface thereof, and

5 Figure 4 shows schematically a third control unit according to the invention and a user interface thereof.

For the sake of clarity, the figures show the invention in a simplified form. Like reference numerals refer to like parts.

The rock drilling apparatus shown in Figure 1 comprises a carrier 1,  
10 a power unit 2 arranged on the carrier, a control cabin 3 and in this case three drilling booms 4 that are movable with respect to the carrier. The free end of each drilling boom 4 is provided with a feeding beam 5 with a rock drill 6 arranged movably therein. The rock drill 6, the feeding beam 5 and the drilling boom 4 form a unit referred to herein as a drilling unit 7. For the sake of clarity,  
15 Figure 1 does not show any accessory equipment required for drilling, such as devices related to replacement of drill rods 8 and a drill bit 9. The rock drilling apparatus further comprises a control unit 10 arranged on the carrier 1, preferably in the control cabin in connection with the equipment for controlling the rock drilling apparatus. The control unit 10 receives measurement data on e.g.  
20 impact pressure, feed pressure, feed flow, feed rate, rate of rotation, rotation pressure, rotation pressure medium flow, flow of flushing agent, sound pressure intensity, and vibration via a line 11a from sensors 11 arranged in the drilling units 7. The control unit transmits control commands via a control line 21 to the drilling units 7 to control them.

25 Figure 2 shows a control unit 10 of a rock drilling apparatus. The control unit 10 comprises a keypad 12 for inputting data into the memory of the control unit. For example the default settings of the drilling equipment, such as data about the drill, drill rods, drill bit etc., can be supplied via the keypad to the control unit. Alternatively, the default settings can be read by a suitable reading  
30 device 13 for example from a memory disc or transferred from a unit outside the rock drilling apparatus via a wired or a wireless data transmission connection. The control unit shown in the figure comprises four control modes M1 – M4, and the desired control mode can be selected by means of selecting switches 14. In this case the operator selects one control mode at a time, the  
35 control strategy of the control mode being used by the control unit to control the drilling.

The control modes M1 – M4 shown in Figure 2 can be determined e.g. according to the following control strategies:

5 M1 = drilling efficiency mode that measures the rate at which the drill tool penetrates the rock. The drilling efficiency mode M1 comprises adjusting the operating parameters to obtain a maximum penetration rate. Therefore the target criterion is the maximum penetration rate. Alternatively, the target criterion of the drilling efficiency mode can be drilling at a substantially constant penetration rate. The control unit adjusts the penetration rate e.g. by varying the feed force, impact power and rotation torque.

10 M2 = quality mode, which measures e.g. the rotation torque acting on the drill tool. The quality mode M2 comprises adjusting the operating parameters so that the rotation torque remains within predetermined limits. It is also possible to measure the feed force and to adjust the feeding so as to avoid overfeed during the drilling, since this usually makes the hole to be  
15 drilled less straight. Sufficient straightness of a hole, which can be one of the target criteria of the quality mode, is obtained by using a low impact power. One of the characteristics illustrating the quality of drilling can be the ease of unscrewing the threaded connections between the drilling components. The connections can be opened more easily when overfeed is avoided during the  
20 drilling.

M3 = cost mode that measures e.g. vibration occurring in the drilling equipment. The cost mode M3 comprises adjusting the operating parameters so as to minimize the vibration. The cost mode determines limits for allowed vibrations. Diminishing vibration lengthens the service life of the drilling equip-  
25 ment, thus minimizing costs of spare parts, and idle time resulting from repairs. The target criterion of this mode is the service life of the drilling equipment. In order to minimize vibration, the aim is to avoid both underfeed and overfeed, and a high impact power and rotation torque during the drilling.

30 M4 = optimisation mode, where the control unit automatically adjusts the operating parameters one at a time. The mode comprises measuring a change in the measuring values caused by the operating parameter that is being adjusted. Measuring values have preset limits. When adjustment of an individual operating parameter provides the allowed area preset for a measuring value, this adjustment value is locked and a new operating parameter is  
35 selected and adjusted to obtain the allowed area preset for the measuring value. The adjustment is continued in this manner as a continuous cycle.

Fulfilment of the target criteria requires fulfilment of certain measurable criteria.

Figure 3 shows another control unit 10, which comprises a keypad 12 and a reading device 13 for supplying default data to the control unit. The control unit further comprises a screen 15 and a graphical user interface. The screen 15 displays a polygonal operating area 16 that defines the area where a control cursor 17 can be moved by means of arrow keys 18. Alternatively, the cursor can be moved with other guides, such as a mouse, a pointing ball or a touch screen. The location of the control cursor 17 in the operating area 16 determines the current operating point of the control system. In this case the operating area 16 is triangular, and each corner 20 of the triangle represents one control mode. The triangle has three control modes: M1, M2 and M3. By moving the control cursor 17 the operator can weight one control mode over the other two modes. In a situation where the control cursor 17 is placed in the centre 19 of the triangle, the distance to each corner 20 is equal and each control mode is thus equally weighted. When the control cursor 17 is moved towards one corner 20, the distance thereto decreases while the distance to the other two corners of the triangle increases. The control system calculates the weighting of the control modes M1, M2 and M3 with respect to the distance from the cursor 17 to the corners 20 of the triangle.

Weighting coefficients used by the control system can be determined as follows:

- calculating the maximum distance R of the cursor by formula  

$$R = \text{Sqrt}((X1-X0)^2 + (Y1-Y0)^2)$$
- calculating weighting coefficients C0, C1, C2 by subtracting the direct distance to the corner from the maximum distance R  

$$C0 = R - \text{Sqrt}((XX-X0)^2 + (YY-Y0)^2)$$

$$C1 = R - \text{Sqrt}((XX-X1)^2 + (Y1-YY)^2)$$

$$C2 = R - \text{Sqrt}((X2-XX)^2 + (YY-Y2)^2),$$
 followed by
  - calculating limits for the measurement data, and control values of individual operating parameters by means of the weighting coefficients C0, C1, C2.

Furthermore, the graphical user interface enables the operator to select the desired control modes M1 – M3 to the corners 20 of the operating



area 16 from the memory of the control unit 10. Also, the control unit can store different operating areas 16, from which the operator can choose one.

Figure 4 shows yet another control unit 10, where four control modes M1, M2, M3 and M4 are arranged in a square. In this case the control cursor 17 is a mechanical guide, such as a joystick or the like, the location of the guide within the square operating area 16 determining the operating point of the control system. Similarly as in the arrangement shown in Figure 3, the control system utilizes the distance between the cursor and an individual control mode to calculate, for each control mode, the weighting coefficients corresponding to the operating point, and it thereafter calculates the operating parameters for the drilling by means of the coefficients.

Operating areas 16 of other shapes are also possible, depending on the number of the control modes to be used, for instance. In the simplest form the operating area can be a line segment, where two control modes are arranged at the end points of the line segment. Moving the control cursor towards one end point of the line segment simultaneously lengthens the distance to the other end point, thus decreasing the weighting of the control mode at the other end point.

It should further be mentioned that the criterion to be measured, mentioned in the control mode, can be e.g. the noise of drilling, state of motion of the shank, temperature of the drilling equipment, or strain of the drill rod, in addition to the criteria disclosed above.

When the rock drill and/or the feed means are operated by a pressurized medium, the pressure and flow of the pressurized medium acting on the equipment are measured. Correspondingly, the operating parameters include impact pressure, feed pressure, feed flow, rotation pressure, rotation flow, and pressure and flow of the flushing agent. On the other hand, when the drilling equipment is operated electrically, the sensors measure electrical values, such as voltage and current. Correspondingly, when the equipment is electrical, the operating parameters are electrical control variables.

The drawings and the related description are only intended to illustrate the inventive idea. The details of the invention can vary within the scope of the claims. Therefore the invention can be applied in all types of rock drilling.

## CLAIMS

1. A method of controlling rock drilling, the method comprising drilling rock with a rock drilling apparatus comprising a carrier (1), a feeding beam (5), a rock drill (6) movable with respect to the feeding beam (5), and a control unit (10) for controlling the rock drilling, the method also comprising providing a memory of the control unit (10) with default settings for drilling, measuring the operation of the apparatus during drilling, and adjusting the operating parameters of drilling to accomplish a desired control operation, **characterized** by
- 10 providing the control unit (10) with at least two control modes (M1 – M4) with different control strategies, each control mode (M1 – M4) determining at least one criterion to be measured during drilling, a threshold value for a measurement result, and at least one adjustable operating parameter, prioritising one control mode over the other modes, and
- 15 calculating, based on the measurement results, control values for the operating parameters to be adjusted in the control unit (10) in order to automatically control the drilling such that the control strategy of the prioritised control mode (M1 – M4) is weighted.
2. A method according to claim 1, **characterized** by providing the operating system of the control unit (10) with at least two simultaneously active control modes (M1 – M4) with different control strategies, and prioritising one control mode over the other modes.
- 20 3. A method according to claim 2, **characterized** by providing the operating system of the control unit (10) with an operating area (16) of the shape of a plane geometrical polygon, selecting the operating point of the control by moving a control cursor (17) in the operating area (16), placing one control mode (M1 – M4) in each corner (20) of the operating area (16), and calculating a weighting coefficient for each control mode (M1 – M4) by means of the distance between the operating point and the corners (20).
- 25 4. A control system for a rock drilling apparatus comprising a carrier (1), a feeding beam (5), a rock drill (6) movable with respect to the feeding beam, a control unit (10) provided with a user interface for controlling the drilling, and at least one sensor (11) for measuring drilling operation, **characterized** in that
- 30 the user interface of the control unit (10) is provided with at least two preformed control modes (M1 – M4),
- 35

each control mode (M1 – M4) has a particular control strategy and determines at least one criterion to be measured during the drilling, a threshold value for a measurement result, and at least one adjustable operating parameter,

5                   one control mode can be prioritised over the other modes, and  
the control unit (10) is arranged to automatically adjust, based on the measurement results, the operating parameters determined by the control modes (M1 – M4) such that the drilling result according to the prioritised control mode is weighted over the other control modes (M1 – M4).

10                  5. A control system according to claim 4, **characterized** in that the user interface of the control unit (10) is provided with at least two simultaneously active control modes (M1 – M4) with different control strategies, and the user interface comprises means for prioritising one control mode over the other modes.

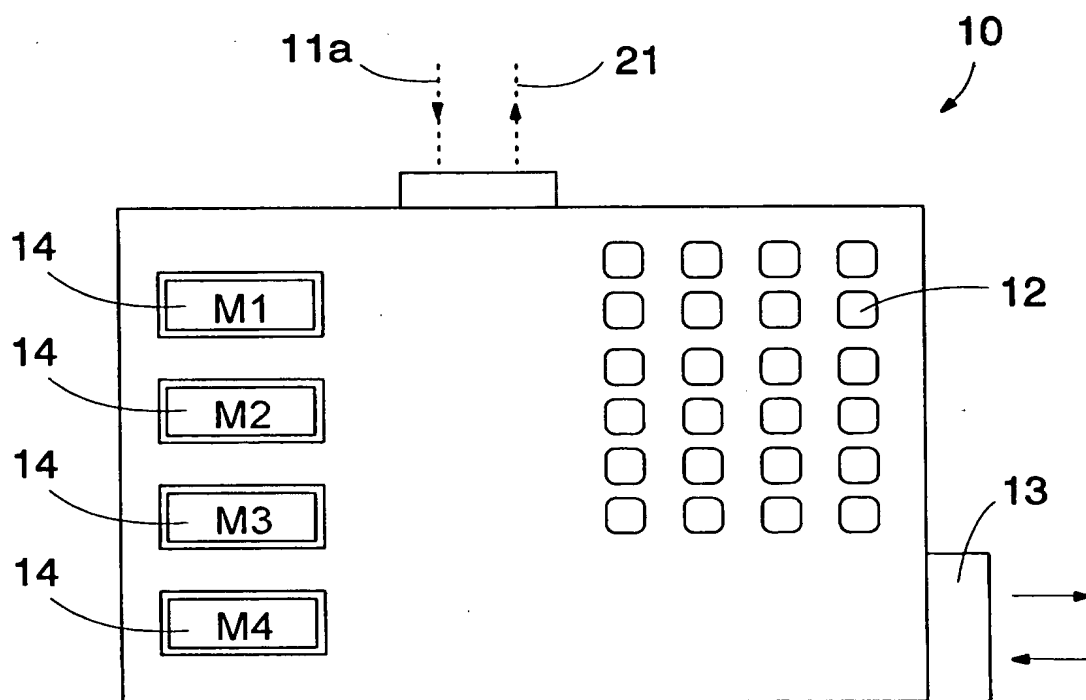
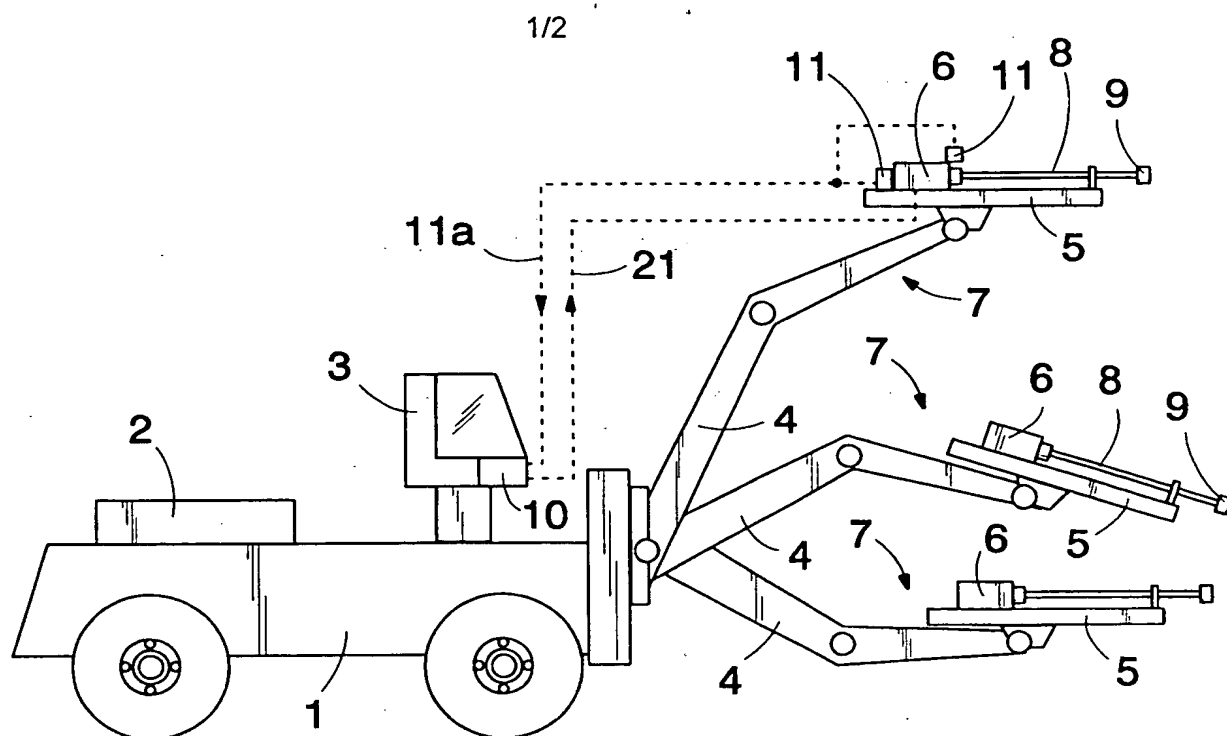
15                  6. A control system according to claim 5, **characterized** in that the user interface of the control unit (10) comprises an operating area (16) of the shape of a plane geometrical polygon, that one control mode (M1 – M4) is placed in each corner (20) of the polygon, that the user interface comprises a control cursor (17) whose location in the operating area (16) is arranged to  
20                  represent the currently selected operating point of the control, and that the control unit (10) is arranged to calculate the weighting of each control mode (M1 – M4) depending on the distance from the operating point to the corners (20) of the polygon.

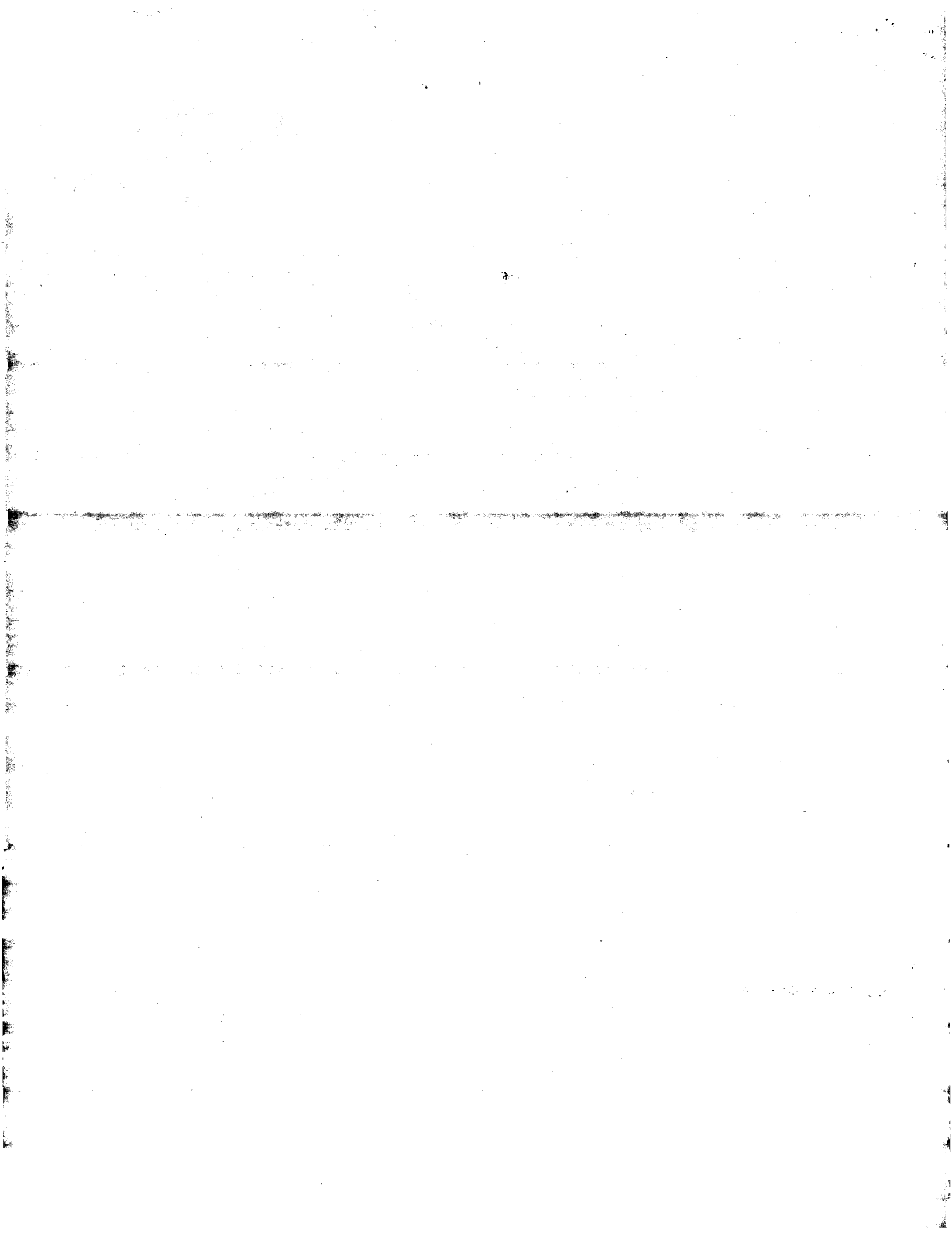
25                  7. A control system according to claim 6, **characterized** in that the operating system comprises a triangular operating area (16).

8. A control system according to claim 7, **characterized** in that the first corner (20) of the triangular operating area (16) is provided with a control mode (M1) optimising the penetration rate of drilling, that the second corner of the triangle is provided with a control mode (M2) optimising the  
30                  straightness of the hole to be drilled, and the third corner of the triangle is provided with a control mode (M3) optimising the service life of the drilling equipment.

9. A control system according to any one of claims 4 to 8, **characterized** in that the control unit (10) comprises a graphical user interface.  
35







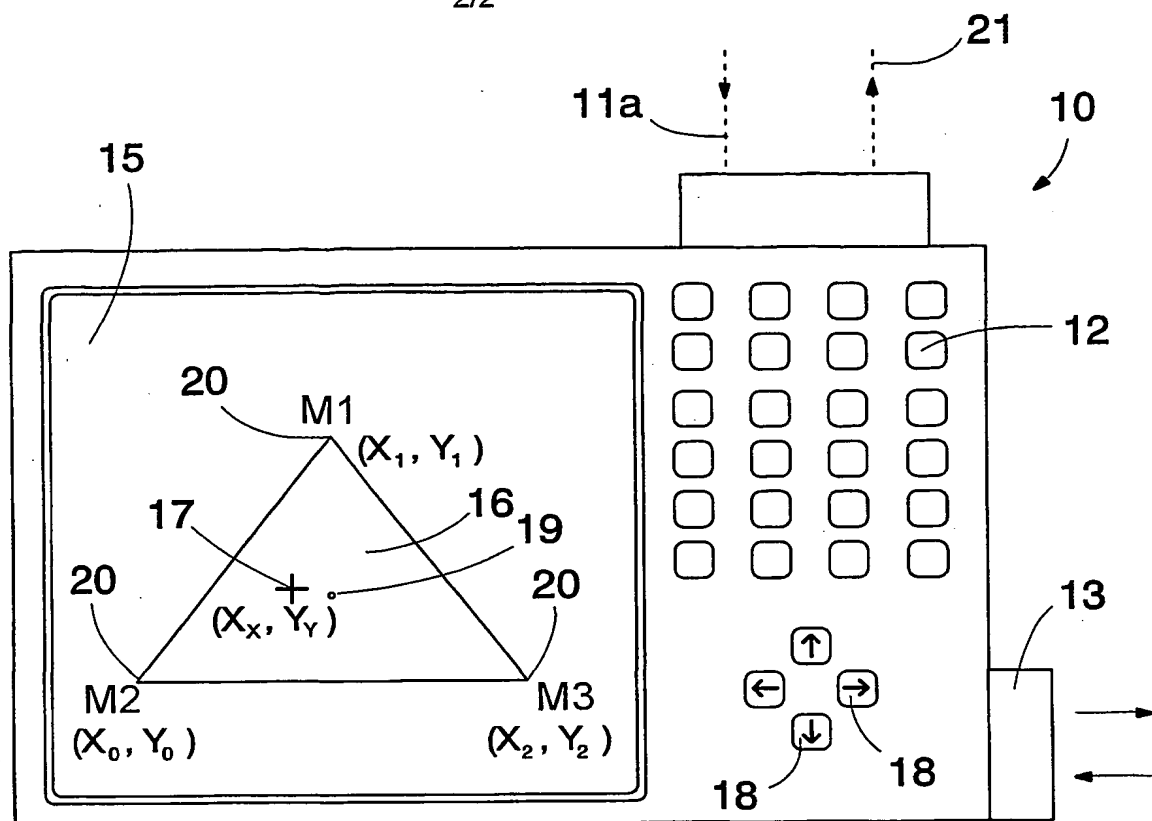


FIG. 3

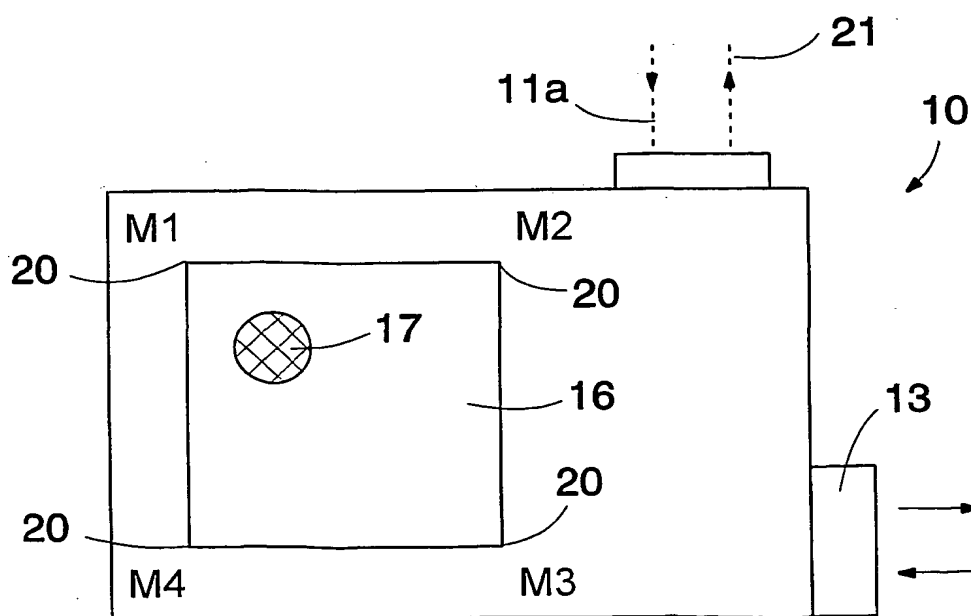


FIG. 4





# INTERNATIONAL SEARCH REPORT

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## A. CLASSIFICATION OF SUBJECT MATTER

IPC7: E21B 44/00

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, PAJ

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages  | Relevant to claim No. |
|-----------|---|-----------------------|
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☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

\* Special categories of cited documents:

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# INTERNATIONAL SEARCH REPORT

Information on patent family members

06/07/02

International application No.

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| Patent document<br>cited in search report |         |    | Publication<br>date | Patent family<br>member(s) |             | Publication<br>date |
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| Date of mailing(day/month/year)<br>21 November 2002 (21.11.02) |   |   |
| Applicant's or agent's file reference<br>2010201PC/or          |   |   |
| International application No.<br>PCT/FI02/000409               | International filing date(day/month/year)<br>14 May 2002 (14.05.02) | Priority date(day/month/year)<br>15 May 2001 (15.05.01) |
| Applicant<br>SANDVIK TAMROCK OY, et al                         |   |   |

**IMPORTANT NOTICE**

1. Notice is hereby given that the International Bureau has **communicated**, as provided in Article 20, the international application to the following designated Offices on the date indicated above as the date of mailing of this notice:

KP, KR, US

In accordance with Rule 47.1(c), third sentence, those Offices will accept the present notice as conclusive evidence that the communication of the international application has duly taken place on the date of mailing indicated above and no copy of the international application is required to be furnished by the applicant to the designated Office(s).

2. The following designated Offices have waived the requirement for such a communication at this time:

AE, AG, AL, AM, AP, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EA, EC, EE, EP, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OA, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZM, ZW

The communication will be made to those Offices only upon their request. Furthermore, those Offices do not require the applicant to furnish a copy of the international application (Rule 49.1(a-bis)).

3. Enclosed with this notice is a copy of the international application as published by the International Bureau on 21 November 2002 (21.11.02) under No. WO 02/092966.

4. **TIME LIMITS for filing a demand for international preliminary examination and for entry into the national phase**

The applicable time limit for entering the national phase will, **subject to what is said in the following paragraph**, be **30 MONTHS** from the priority date, not only in respect of any elected Office if a demand for international preliminary examination is filed before the expiration of **19 months** from the priority date, but also in respect of any designated Office, in the absence of filing of such demand, where Article 22(1) as modified with effect from 1 April 2002 applies in respect of that designated Office. For further details, see *PCT Gazette* No. 44/2001 of 1 November 2001, pages 19926, 19932 and 19934, as well as the *PCT Newsletter*, October and November 2001 and February 2002 issues.

In practice, **time limits other than the 30-month time limit** will continue to apply, for various periods of time, in respect of certain designated or elected Offices. For **regular updates on the applicable time limits** (20, 21, 30 or 31 months, or other time limit), Office by Office, refer to the *PCT Gazette*, the *PCT Newsletter* and the *PCT Applicant's Guide*, Volume II, National Chapters, all available from WIPO's Internet site, at <http://www.wipo.int/pct/en/index.html>.

For filing a **demand for international preliminary examination**, see the *PCT Applicant's Guide*, Volume I/A, Chapter IX. Only an applicant who is a national or resident of a PCT Contracting State which is bound by Chapter II has the right to file a demand for international preliminary examination (at present, all PCT Contracting States are bound by Chapter II).

It is the applicant's **sole responsibility** to monitor all these time limits.

The International Bureau of WIPO  
34, chemin des Colombettes  
1211 Geneva 20, Switzerland

Authorized officer

Judith Zahra

Facsimile No.(41-22) 740.14.35

Telephone No.(41-22) 338.91.11



## PATENT COOPERATION TREATY

PCT

INFORMATION CONCERNING ELECTED  
OFFICES NOTIFIED OF THEIR ELECTION

(PCT Rule 61.3)

From the INTERNATIONAL BUREAU

To:

KOLSTER OY AB  
Iso Roobertinkatu 23  
P.O.Box 148  
FIN-00121 Helsinki  
Finland

|   |  |                       |
|---|--|-----------------------|
| Date of mailing (day/month/year)<br>05 December 2002 (05.12.02) |  |                       |
| Applicant's or agent's file reference<br>2010201PC/or           |  | IMPORTANT INFORMATION |
| International application No.<br>PCT/FI02/00409                 | International filing date (day/month/year)<br>14 May 2002 (14.05.02) |                       |
| Priority date (day/month/year)<br>15 May 2001 (15.05.01)        |  |                       |
| Applicant<br>SANDVIK TAMROCK OY et al                           |  |                       |

1. The applicant is hereby informed that the International Bureau has, according to Article 31(7), notified each of the following Offices of its election:

EP : AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR  
National : AU, BG, CA, CN, DE, GB, IL, JP, KP, KR, MN, NO, PL, RO, RU, SK, US

2. The following Offices have waived the requirement for the notification of their election; the notification will be sent to them by the International Bureau only upon their request:

AP : GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW  
EA : AM, AZ, BY, KG, KZ, MD, RU, TJ, TM  
OA : BF, BJ, CF, CG, CI, CM, GA, GN, GO, GW, ML, MR, NE, SN, TD, TG  
National : AE, AG, AL, AM, AT, AZ, BA, BB, BR, BY, BZ, CH, CO, CR, CU, CZ, DK, DM, DZ, EC, EE, ES, FI, GD, GE, GH, GM, HR, HU, ID, IN, IS, KE, KG, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MW, MX, MZ, NZ, OM, PH, PT, SD, SE, SG, SI, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZM, ZW

3. The applicant is reminded that he must enter the "national phase" **before the expiration of 30 months from the priority date** before each of the Offices listed above. This must be done by paying the national fee(s) and furnishing, if prescribed, a translation of the international application (Article 39(1)(a)), as well as, where applicable, by furnishing a translation of any annexes of the international preliminary examination report (Article 36(3)(b) and Rule 74.1).

Some offices have fixed time limits expiring later than the above-mentioned time limit. For detailed information about the applicable time limits and the acts to be performed upon entry into the national phase before a particular Office, see Volume II of the PCT Applicant's Guide.

The entry into the European regional phase is postponed **until 31 months from the priority date** for all States designated for the purposes of obtaining a European patent.

|   |  |
|---|--|
| The International Bureau of WIPO<br>34, chemin des Colombettes<br>1211 Geneva 20, Switzerland | Authorized officer:<br>El Mostafa MOUSSAID (Fax 338-87-20) |
| Facsimile No. (41-22) 740.14.35   | Telephone No. (41-22) 338.83.38                            |



# PATENT COOPERATION TREATY

# PCT

## INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

|   |   |   |
|---|---|---|
| Applicant's or agent's file reference<br>2010201PC/ko   | <b>FOR FURTHER ACTION</b> See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416) |   |
| International application No.<br>PCT/FI02/00409   | International filing date ( <i>day/month/year</i> )<br>14.05.2002   | Priority date ( <i>day/month/year</i> )<br>15.05.2001 |
| International Patent Classification (IPC) or national classification and IPC <sub>7</sub><br>E21B 44/00 |   |   |
| Applicant<br>Sandvik Tamrock Oy et al   |   |   |

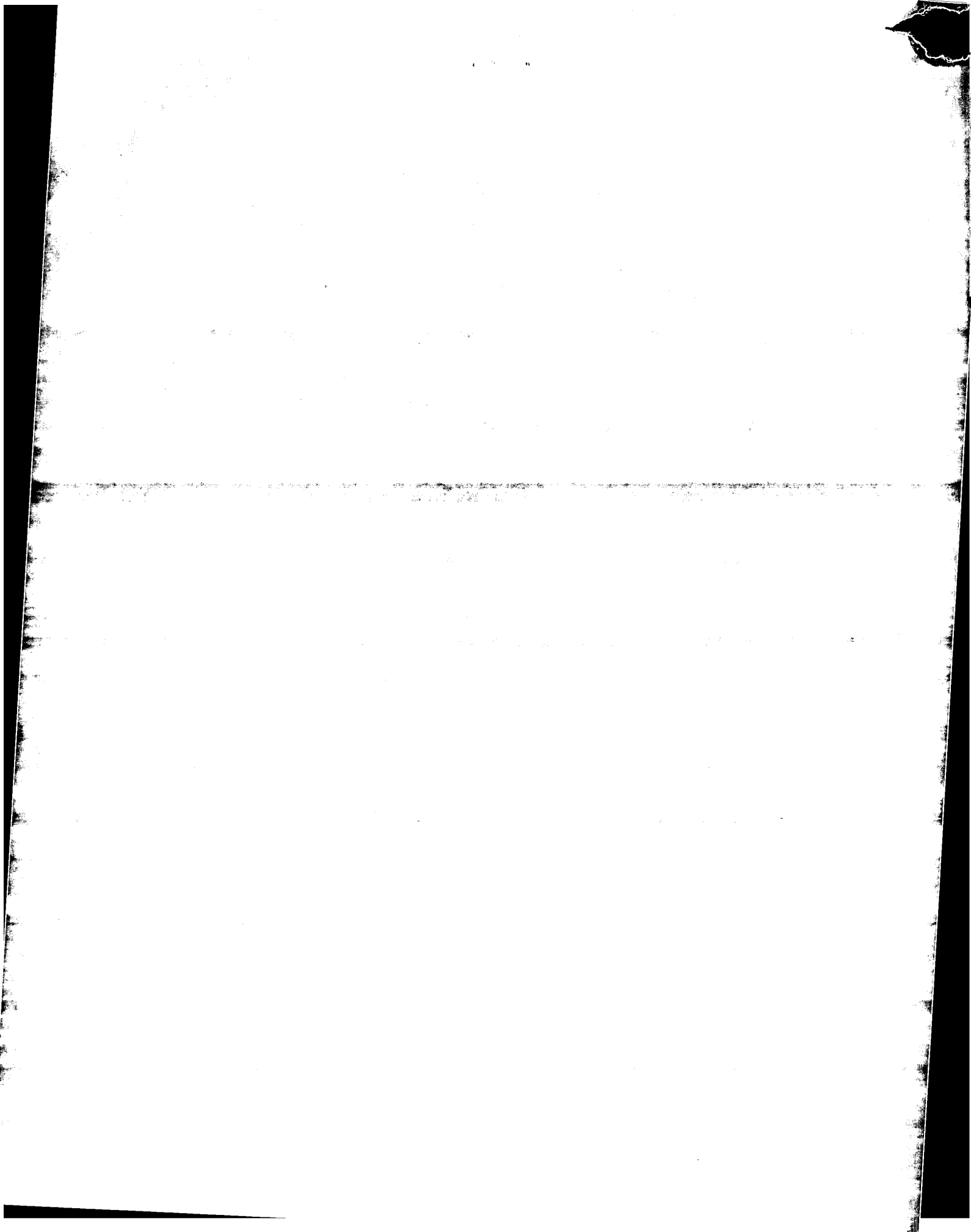
1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 4 sheets, including this cover sheet.  
  
☒ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of 3 sheets.

3. This report contains indications relating to the following items:

- I ☒ Basis of the report
- II ☐ Priority
- III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- IV ☐ Lack of unity of invention
- V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- VI ☐ Certain documents cited
- VII ☐ Certain defects in the international application
- VIII ☐ Certain observations on the international application

|   |   |
|---|---|
| Date of submission of the demand<br><br>21.11.2002  | Date of completion of this report<br><br>03.07.2003                             |
| Name and mailing address of the IPEA/SE<br>Patent- och registreringsverket      Telex<br>Box 5055                                      17978<br>S-102 42 STOCKHOLM                      PATOREG-S<br>Facsimile No. 08-667 72 88 | Authorized officer<br><br>Christer Bäcknert / MRO<br>Telephone No. 08-782 25 00 |





## INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.

PCT/FI02/00409

## I. Basis of the report

## 1. With regard to the elements of the international application:\*

- ☐ the international application as originally filed
- ☒ the description:  
pages 1-7, as originally filed  
pages \_\_\_\_\_, filed with the demand  
pages \_\_\_\_\_, filed with the letter of \_\_\_\_\_
- ☒ the claims:  
pages \_\_\_\_\_, as originally filed  
pages \_\_\_\_\_, as amended (together with any statement) under article 19  
pages \_\_\_\_\_, filed with the demand  
pages 8-10, filed with the letter of 30.05.2003
- ☒ the drawings:  
pages 1-2, as originally filed  
pages \_\_\_\_\_, filed with the demand  
pages \_\_\_\_\_, filed with the letter of \_\_\_\_\_
- ☐ the sequence listing part of the description:  
pages \_\_\_\_\_, as originally filed  
pages \_\_\_\_\_, filed with the demand  
pages \_\_\_\_\_, filed with the letter of \_\_\_\_\_

## 2. With regard to the language, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language \_\_\_\_\_ which is:

- ☐ the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

## 3. With regard to any nucleotide and/or amino acid sequence disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. ☐ The amendments have resulted in the cancellation of:

- ☐ the description, pages \_\_\_\_\_
- ☐ the claims, Nos. \_\_\_\_\_
- ☐ the drawings, sheet/fig \_\_\_\_\_

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2 (c)).\*\*

\* Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).

\*\* Any replacement sheet containing such amendments must be referred to under item I and annexed to this report.



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## INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.

PCT/FI02/00409

**V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement****1. Statement**

|                               |        |            |     |
|-------------------------------|--------|------------|-----|
| Novelty (N)                   | Claims | <u>1-7</u> | YES |
|                               | Claims | _____      | NO  |
| Inventive step (IS)           | Claims | <u>1-7</u> | YES |
|                               | Claims | _____      | NO  |
| Industrial applicability (IA) | Claims | <u>1-7</u> | YES |
|                               | Claims | _____      | NO  |

**2. Citations and explanations (Rule 70.7)**

The International Search Report cites these documents:

D1: US 5679894 A  
D2: US 5713422 A  
D3: WO 0042284 A1

All cited documents disclose methods and systems for controlling rock drilling, wherein the control unit is provided with a plurality of drilling strategies among which the operator can choose. When the operator chooses a control mode, this mode is prioritised over the others.

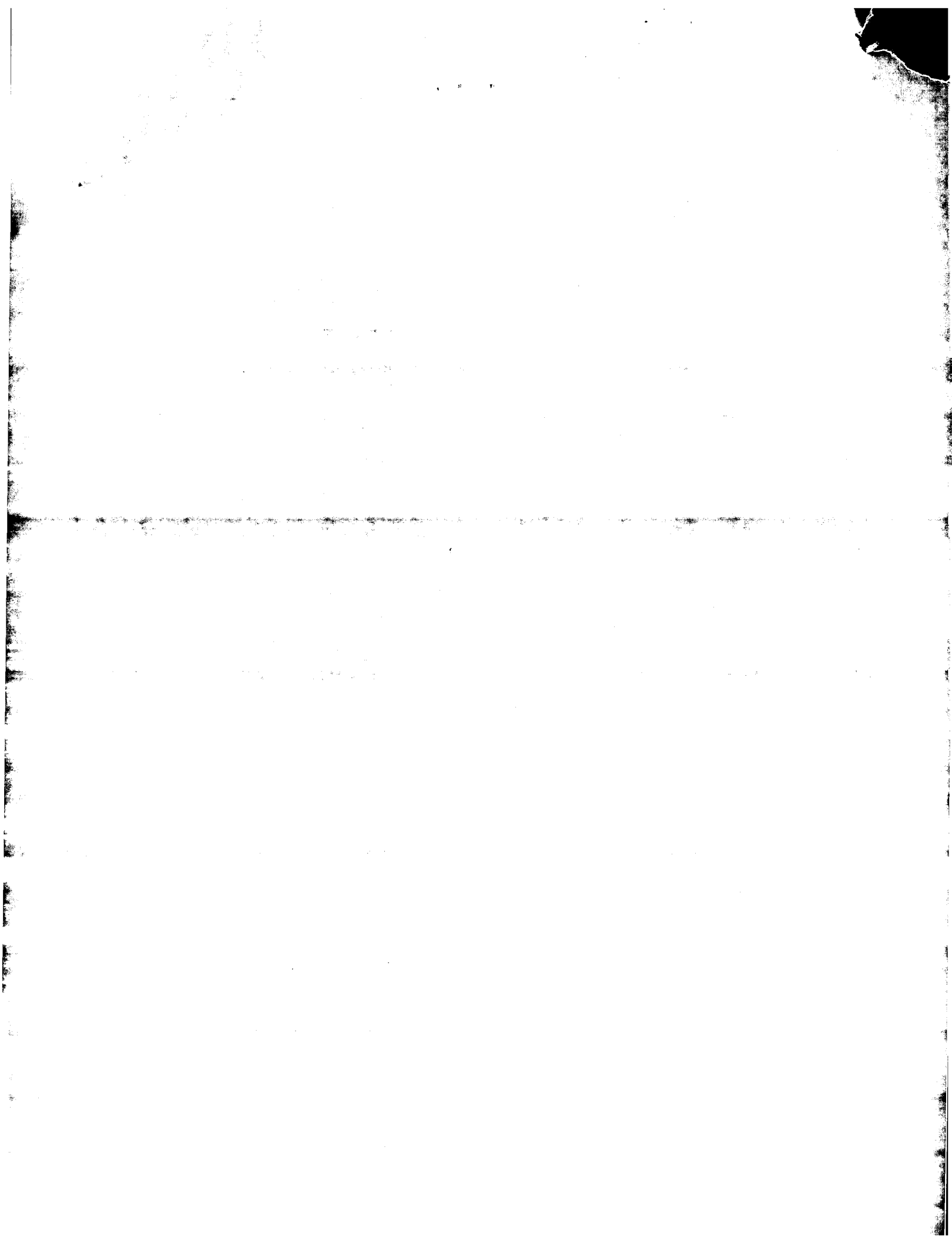
D1 is considered to represent the prior art closest to the claimed invention. A control unit may be programmed to control the drilling in a number of control modes. The control modes can be based on a single measured parameter or a number of parameters combined.

The claimed invention differs from this prior art in that at least two control modes, with different control strategies, are simultaneously active in the operating system of the control unit, in that one control mode is prioritised and in that the prioritised control strategy is weighted.

The cited documents represent the general state of the art. The invention defined in claims 1-7 is not disclosed by any of these documents.

The cited prior art does not give any indication that would lead a person skilled in the art to the claimed method and control system for controlling rock drilling. Therefore, the

.../...



INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.

PCT/FI02/00409

**Supplemental B x**

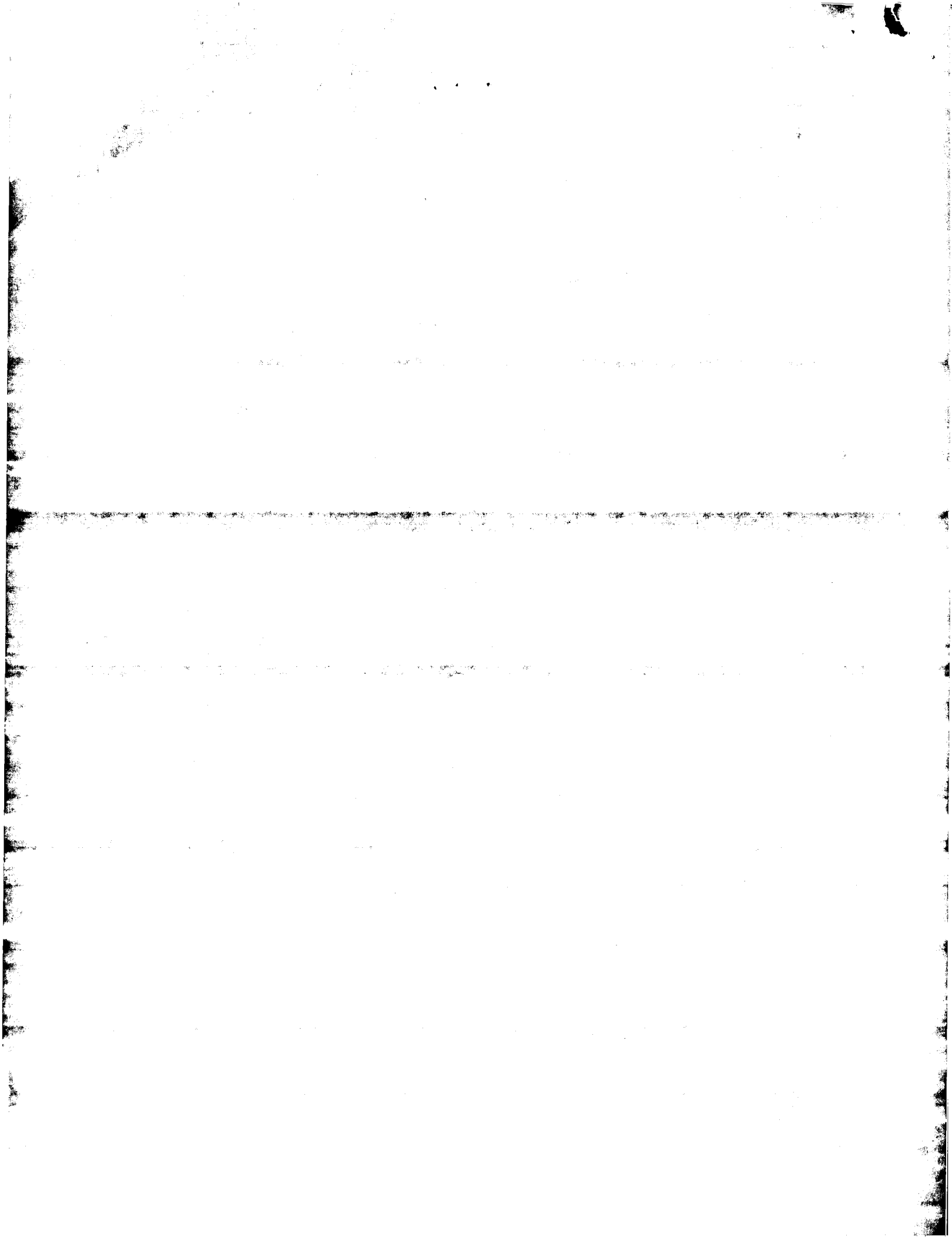
(To be used when the space in any of the preceding boxes is not sufficient)

Continuation of: Box V

claimed invention is not obvious to a person skilled in the art.

Accordingly, the invention defined in claims 1-7 is novel and is considered to involve an inventive step.

The invention is industrially applicable.



CLAIMS

1. A method of controlling rock drilling, the method comprising  
drilling rock with a rock drilling apparatus comprising a carrier (1), a  
feeding beam (5), a rock drill (6) movable with respect to the feeding beam (5),  
5 and a control unit (10) for controlling the rock drilling,  
providing a memory of the control unit (10) with default settings for  
drilling,  
measuring the operation of the apparatus during drilling, and adjust-  
ing the operating parameters of drilling to accomplish a desired control opera-  
10 tion,  
providing the control unit (10) with at least two control modes (M1 –  
M4), each control mode (M1 – M4) determining at least one criterion to be  
measured during drilling, a threshold value for a measurement result, and at  
least one adjustable operating parameter,  
15 **characterized by**  
providing the operating system of the control unit (10) with at least  
two simultaneously active control modes (M1 – M4) with different control  
strategies,  
prioritising one control mode over the other modes, and  
20 calculating, based on the measurement results, control values for  
the operating parameters to be adjusted in the control unit (10) in order to  
automatically control the drilling such that the control strategy of the prioritised  
control mode (M1 – M4) is weighted.  
2. A method according to claim 1, **characterized by**  
25 providing the control unit (10) with a user interface  
arranging an operating area (16) of the shape of a plane geometri-  
cal polygon in the user interface,  
selecting the operating point of the control by moving a control cur-  
sor (17) in the operating area (16),  
30 placing one control mode (M1 – M4) in each corner (20) of the op-  
erating area (16), and  
calculating a weighting coefficient for each control mode (M1 – M4)  
by means of the distance between the operating point and the corners (20).  
3. A control system for a rock drilling apparatus comprising a carrier  
35 (1), a feeding beam (5), a rock drill (6) movable with respect to the feeding





beam, a control unit (10) provided with a user interface for controlling the drilling, and at least one sensor (11) for measuring drilling operation, and wherein the operating system is provided with at least two preformed control modes (M1 – M4),

5 each control mode (M1 – M4) determines at least one criterion to be measured during the drilling, a threshold value for a measurement result, and at least one adjustable operating parameter, **characterized** in that

the operating system is provided with at least two simultaneously active control modes (M1 – M4) with different control strategies,

10 one control mode can be prioritised over the other modes, and the control unit (10) is arranged to automatically adjust, based on the measurement results, the operating parameters determined by the control modes (M1 – M4) such that the drilling result according to the prioritised control mode is weighted over the other control modes (M1 – M4).

15 4. A control system according to claim 3, **characterized** in that

the control unit (10) comprises a user interface,

the user interface of the control unit (10) comprises an operating area (16) of the shape of a plane geometrical polygon,

20 one control mode (M1 – M4) is placed in each corner (20) of the polygon,

the user interface comprises a control cursor (17) whose location in the operating area (16) is arranged to represent the currently selected operating point of the control, and

25 the control unit (10) is arranged to calculate the weighting of each control mode (M1 – M4) depending on the distance from the operating point to the corners (20) of the polygon.

5. A control system according to claim 4, **characterized** in that the operating system comprises a triangular operating area (16).

30 6. A control system according to claim 5, **characterized** in that

the first corner (20) of the triangular operating area (16) is provided with a control mode (M1) optimising the penetration rate of drilling,

35 the second corner of the triangle is provided with a control mode (M2) optimising the straightness of the hole to be drilled, and



10

the third corner of the triangle is provided with a control mode (M3) optimising the service life of the drilling equipment.

7. A control system according to any one of claims 3 to 6, **characterized** in that the control unit (10) comprises a graphical user interface.
- 5



# RECORD COPY

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## PCT REQUEST

2010201PC/or

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|         |   |  |
|---------|---|--|
| 0       | For receiving Office use only   |  |
| 0-1     | International Application No.   | PCT/FI02/00409   |
| 0-2     | International Filing Date   | 14 MAY 2002 (14-05-2002)                                     |
| 0-3     | Name of receiving Office and "PCT International Application"  | The Finnish Patent Office<br>PCT International Application   |
| 0-4     | Form - PCT/RO/101 PCT Request   |  |
| 0-4-1   | Prepared using  | PCT-EASY Version 2.92<br>(updated 01.01.2002)                |
| 0-5     | Petition<br>The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty |  |
| 0-6     | Receiving Office (specified by the applicant)   | National Board of Patents and Registration (Finland) (RO/FI) |
| 0-7     | Applicant's or agent's file reference   | 2010201PC/or   |
| I       | Title of invention  | DRILLING CONTROL ARRANGEMENT                                 |
| II      | Applicant   |  |
| II-1    | This person is:   | applicant only   |
| II-2    | Applicant for   | all designated States except US                              |
| II-4    | Name  | SANDVIK TAMROCK OY   |
| II-5    | Address:  | Pihtisulunkatu 9<br>FIN-33330 Tampere<br>Finland             |
| II-6    | State of nationality  | FI   |
| II-7    | State of residence  | FI   |
| III-1   | Applicant and/or inventor   |  |
| III-1-1 | This person is:   | applicant and inventor                                       |
| III-1-2 | Applicant for   | US only  |
| III-1-4 | Name (LAST, First)  | SALMINEN, Pekka  |
| III-1-5 | Address:  | Pitkänienkatu 11<br>FIN-33330 Tampere<br>Finland             |
| III-1-6 | State of nationality  | FI   |
| III-1-7 | State of residence  | FI   |

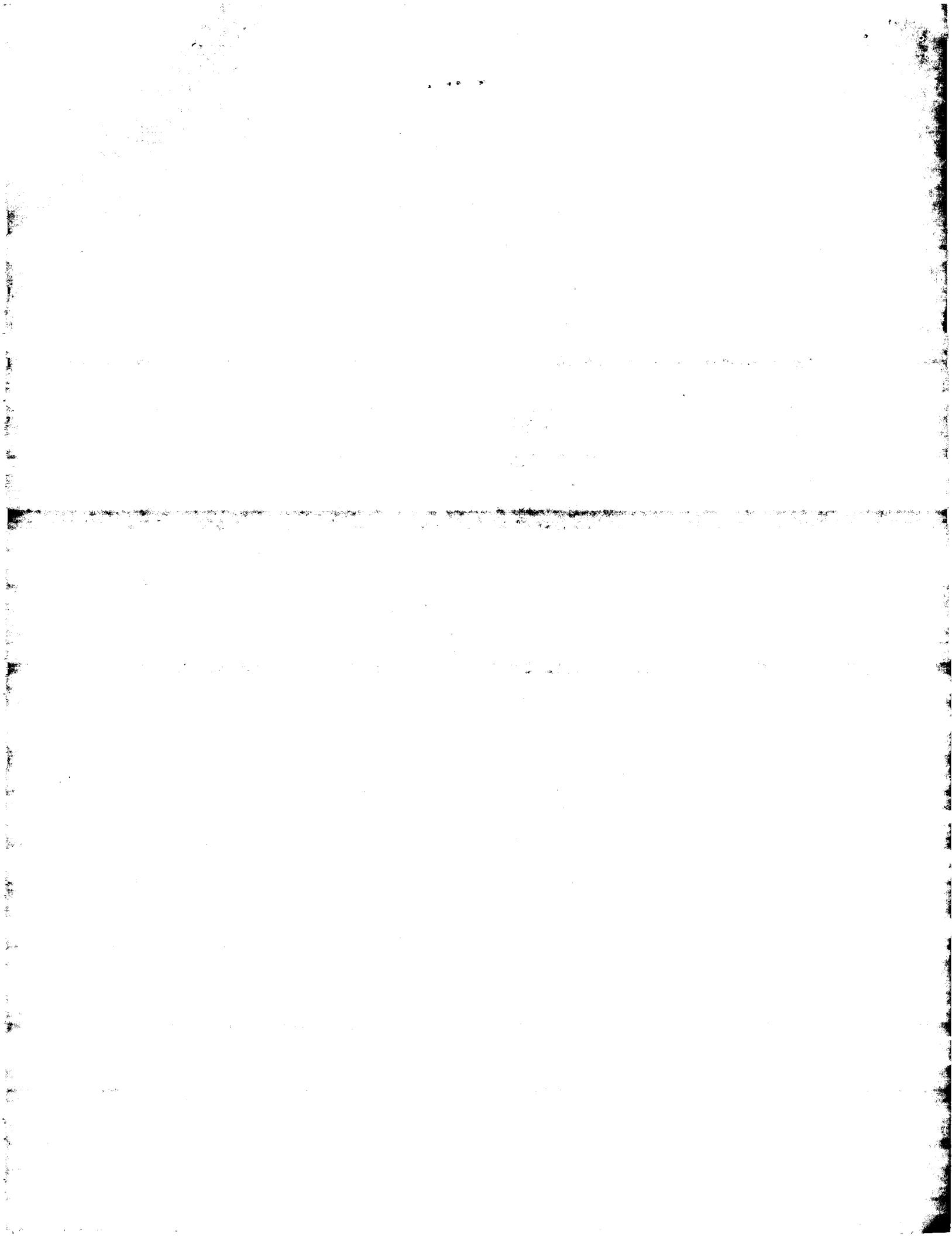


## PCT REQUEST

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|         |  |   |
|---------|--|---|
| III-2   | <b>Applicant and/ r inv nt r</b>   |   |
| III-2-1 | This person is:  | applicant and inventor  |
| III-2-2 | Applicant for  | US only   |
| III-2-4 | Name (LAST, First)   | SAHA, Heikki  |
| III-2-5 | Address:   | Karjakontie 4 C<br>FIN-33340 Tampere<br>Finland   |
| III-2-6 | State of nationality   | FI  |
| III-2-7 | State of residence   | FI  |
| IV-1    | <b>Agent or common representative; or address for correspondence</b><br>The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as: | agent   |
| IV-1-1  | Name   | KOLSTER OY AB   |
| IV-1-2  | Address:   | Iso Roobertinkatu 23<br>P.O.Box 148<br>FIN-00121 Helsinki<br>Finland  |
| IV-1-3  | Telephone No.  | + 358 9 618 821   |
| IV-1-4  | Facsimile No.  | + 358 9 602 244   |
| IV-1-5  | e-mail   | kolster@kolster.fi  |
| V       | <b>Designation of States</b>   |   |
| V-1     | Regional Patent<br>(other kinds of protection or treatment, if any, are specified between parentheses after the designation(s) concerned)  | AP: GH GM KE LS MW MZ SD SL SZ TZ UG ZM<br>ZW and any other State which is a Contracting State of the Harare Protocol and of the PCT<br>EA: AM AZ BY KG KZ MD RU TJ TM and any other State which is a Contracting State of the Eurasian Patent Convention and of the PCT<br>EP: AT BE CH&LI CY DE DK ES FI FR GB GR IE IT LU MC NL PT SE TR and any other State which is a Contracting State of the European Patent Convention and of the PCT<br>OA: BF BJ CF CG CI CM GA GN GQ GW ML MR NE SN TD TG and any other State which is a member State of OAPI and a Contracting State of the PCT |





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|        |  |  |
|--------|--|--|
| V-2    | National Patent<br>(other kinds of protection or treatment, if any, are specified between parentheses after the designation(s) concerned)  | AE AG AL AM AT (patent and utility model) AU AZ BA BB BG BR BY BZ CA CH&LI CN CO CR CU CZ (patent and utility model) DE (patent and utility model) DK (patent and utility model) DM DZ EC EE (patent and utility model) ES FI (patent and utility model) GB GD GE GH GM HR HU ID IL IN IS JP KE KG KP KR KZ LC LK LR LS LT LU LV MA MD MG MK MN MW MX MZ NO NZ OM PH PL PT RO RU SD SE SG SI SK (patent and utility model) SL TJ TM TN TR TT TZ UA UG US UZ VN YU ZA ZM ZW |
| V-5    | Precautionary Designation Statement<br><br>In addition to the designations made under items V-1, V-2 and V-3, the applicant also makes under Rule 4.9(b) all designations which would be permitted under the PCT except any designation(s) of the State(s) indicated under item V-6 below. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit. |  |
| V-6    | Exclusion(s) from precautionary designations   | NONE   |
| VI-1   | Priority claim of earlier national application   |  |
| VI-1-1 | Filing date  | 15 May 2001 (15.05.2001)   |
| VI-1-2 | Number   | 20011021   |
| VI-1-3 | Country  | FI   |
| VI-2   | Priority document request<br><br>The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) identified above as item(s):   | VI-1   |
| VII-1  | International Searching Authority Chosen   | Swedish Patent Office (ISA/SE)   |



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| VIII   | Declarations   | Number of declarations |  |
|--------|--|------------------------|--|
| VIII-1 | Declaration as to the identity of the inventor   | -                      |  |
| VIII-2 | Declaration as to the applicant's entitlement, as at the international filing date, to apply for and be granted a patent             | 1                      |  |
| VIII-3 | Declaration as to the applicant's entitlement, as at the international filing date, to claim the priority of the earlier application | -                      |  |
| VIII-4 | Declaration of inventorship (only for the purposes of the designation of the United States of America)                               | -                      |  |
| VIII-5 | Declaration as to non-prejudicial disclosures or exceptions to lack of novelty   | -                      |  |



## PCT REQUEST

2010201PC/or

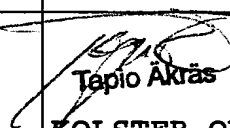
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|                  |  |  |
|------------------|--|--|
| VIII-2-1         | <b>Declaration: Entitlement to apply for and be granted a patent</b><br>Declaration as to the applicant's entitlement, as at the international filing date, to apply for and be granted a patent (Rules 4.17(ii) and 51bis.1(a)(ii)), in a case where the declaration under Rule 4.17(iv) is not appropriate:<br>Name: | <b>in relation to this international application</b><br><br><b>SANDVIK TAMROCK OY</b><br><b>is entitled to apply for and be granted a patent by virtue of the following:</b> |
| VIII-2-1<br>(ii) |  | <b>SANDVIK TAMROCK OY is entitled as employer of the inventor, SALMINEN, Pekka</b>   |
| VIII-2-1<br>(ii) |  | <b>SANDVIK TAMROCK OY is entitled as employer of the inventor, SAHA, Heikki</b>  |
| VIII-2-1<br>(ix) | <b>This declaration is made for the purposes of:</b>   | <b>all designations except the designation of the United States of America</b>   |



## PCT REQUEST

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| IX    | Check list   | number of sheets   | electronic file(s) attached |
|-------|--|--|-----------------------------|
| IX-1  | Request (including declaration sheets)                     | 6  | -                           |
| IX-2  | Description  | 7  | -                           |
| IX-3  | Claims   | 2  | -                           |
| IX-4  | Abstract   | 1  | EZABST00.TXT                |
| IX-5  | Drawings   | 2  | -                           |
| IX-7  | TOTAL  | 18   |                             |
|       | Accompanying items   | paper document(s) attached   | electronic file(s) attached |
| IX-8  | Fee calculation sheet                                      | ✓  | -                           |
| IX-9  | Original separate power of attorney                        | ✓  | -                           |
| IX-11 | Copy of general power of attorney                          | reference no. <no.>  | -                           |
| IX-17 | PCT-EASY diskette  | -  | Diskette                    |
| IX-18 | Other (specified):   | Copy of Official Action  | -                           |
| IX-19 | Figure of the drawings which should accompany the abstract | 3  |                             |
| IX-20 | Language of filing of the international application        | English  |                             |
| X-1   | Signature of applicant, agent or common representative     | <br>Tapio Akräs |                             |
| X-1-1 | Name   | KOLSTER OY AB  |                             |

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|--------|---|--------------------------|
| 10-1   | Date of actual receipt of the purported international application   | 14 MAY 2002 (14-05-2002) |
| 10-2   | Drawings:   |                          |
| 10-2-1 | Received  |                          |
| 10-2-2 | Not received  |                          |
| 10-3   | Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application |                          |
| 10-4   | Date of timely receipt of the required corrections under PCT Article 11(2)  |                          |
| 10-5   | International Searching Authority   | ISA/SE                   |
| 10-6   | Transmittal of search copy delayed until search fee is paid   |                          |

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| 11-1 | Date of receipt of the record copy by the International Bureau |  |
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